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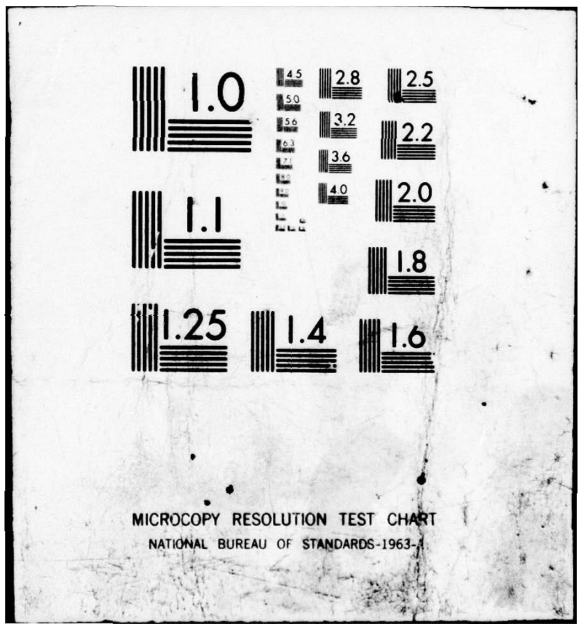
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DST-1810R-487-79-VOL 2-RPT 3

FOREIGN

food technology

OF MILITARY SIGNIFICANCE

15 September 1979

Vol 2, No. 3

A quarterly report reviewing developments in foreign food and food-related technologies possessing military significance including food chemistry, microbiology, packaging, processing, nutrition, rations, and food service.

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PREPARED BY

US ARMY

ARMY MATERIEL DEVELOPMENT & READINESS COMMAND

FOREIGN SCIENCE & TECHNOLOGY CENTER

Preface

The purpose of this publication is to inform members of the military community involved with providing subsistence to US troops about foreign food-related activities of military significance.

This issue features a condensation of a report prepared by FSTC in response to a stated requirement by the Deputy Assistant Secretary of the Army (Research and Development) for a survey and assessment of foreign interest in the preservation of food by ionizing radiation. The original report was prepared to provide assistance in the evaluation of the US Food Irradiation Program in relation to both international food irradiation activities and accomplishments, and to other countries' efforts to introduce irradiation processing of food. Readers interested in the full report may call or write the authors, Victoria Dibbern or Deborah L. Graf, US Army Foreign Science and Technology Center, 220 Seventh Street, NE, Charlottesville, VA 22901, ATTN: DRXST-MT2. (AV 274-7433)

Constructive criticisms, comments, or suggested changes are encouraged and should be forwarded to the Commander, US Army Foreign Science and Technology Center, Charlottesville, VA 22901 (ATTN: DRXST-PO).

6 Foreign Food Technology of Military Significance. Volume 2, Number 3. An Assessment of the International Commitment to Food Irradiation.

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SUMMARY

Fifty countries, approximately the same number as in the 1960s, have food irradiation programs. No country with a previous program is known to have ceased all activity and interest in food irradiation processing. While some well-funded programs in industrial nations have been cut back, many programs in developing countries have received increased support.

Europe, Japan, and certain less developed countries are making significant progress toward using irradiation as a food preservation process. The effort is limited, however, to irradiation at doses less than 1.0 Mrd, and primarily for the purpose of extending shelf life by the destruction of pathogens and molds, by disinfestation, and by the inhibition of sprouting or maturation. While foreign countries have shown interest in the use of sterilizing doses of irradiation, no effort is being expended in this area except for special hospital diets for patients requiring sterile foods. Other countries apparently are willing to wait for the United States to work out the technical and wholesomeness questions of radiation sterilization. Perhaps with the successful international commercialization of food irradiated at low doses, the higher dose levels will be considered, but only if the United States achieves some success [including clearance from the US Food and Drug Administration (FDA)] with its radiation sterilization program.

No country's military departments are known to be contributing financial or personnel support to food irradiation programs, except for Iran (the effect of the revolution on Iran's program has not been determined) and possibly the USSR.

Food preservation by irradiation must still overcome three hurdles: (1) The resolution of questions concerning wholesomeness, (2) the establishment of international legislative controls, and (3) the identification of the market situation in which irradiation will satisfy a need more economically than present practices.

Probably within 5 years the question will be resolved whether most food products irradiated at doses up to 1.0 Mrd are wholesome. In 1976, the Joint IAEA/FAO/WHO* Expert Committee on the Wholesomeness of

*IAEA = International Atomic Energy Agency
FAO = Food and Agriculture Organization
WHO = World Health Organization

Irradiated Foods approved eight foods (three conditionally) as wholesome when irradiated at various doses up to 1.0 Mrd. Data are being collected worldwide for the Committee's 1980 deliberations, when it is hoped that the wholesomeness of practically all food products irradiated up to 1.0 Mrd will be certified.

The situation of clearances on a national basis provides no legislative controls for international trade. To facilitate the international alignment of relevant national standards and recommendations, the Codex Alimentarius (the Joint FAO/WHO Food Standards Program) Commission will consider in December 1979 adopting for all 114 member countries a general standard for the irradiation of eight foods and a code of practice for the operation of food irradiation facilities. Eventually, if the Joint IAEA/FAO/WHO Expert Committee approves virtually all foods irradiated up to 1.0 Mrd, then the Codex Standards are expected to be amended to reflect the Expert Committee's recommendations.

Many countries appear to be awaiting the establishment of the Codex Standards to begin commercial-scale import-export of irradiated foods; these countries include South Africa, the Netherlands, France, Italy, Iceland, Hungary, Belgium, Iraq, India, Israel, and perhaps Egypt. There are rumors of some international trade, but no country is ready to admit this activity until international clearances and standards exist.

The International Facility for Food Irradiation Technology (IFFIT) [sponsored by the IAEA, FAO, OECD (Organization for Economic Cooperation and Development), several cooperatives, and 22 contributing countries ($25 000 each)] is being established at Wageningen with the support of the Netherlands Government. The mission of this facility is to bridge the gap between research and commercial application by providing in-plant training of personnel, especially from developing countries, in the field of food irradiation. The IFFIT will attempt to insure that the preparation of irradiation facilities conforms to the Codex General Standard for Irradiated Foods and the Code of Practice for Operation of Radiation Facilities Used for the Treatment of Foods.

All pilot- and production-size food irradiation facilities in the world, with the possible exception of some in Italy, are believed to have received some governmental funds for construction and, in many cases, for operating expenses.

During the 1960s, the US FDA was considered the world health authority on the wholesomeness of irradiated foods. This is no longer true; the most respected opinion and judgment comes from the Joint

IAEA/FAO/WHO Expert Committee on the Wholesomeness of Irradiated Foods. Whether the US FDA approves foods irradiated up to 1.0 Mrd for consumption in the United States or continues to postpone the decision will likely have no effect on any other country's food irradiation program. The decisions regarding wholesomeness, as well as legislation, are being made by international committees that are dominated by Europeans.

The current optimism about food irradiation becoming a viable preservation technique rests on a revised view of what constitutes proof of wholesomeness. The general approach to wholesomeness testing of irradiated foods is changing toward a broader view; i.e., (1) that irradiation is a "process" rather than an "additive," and (2) that food commodities should be categorized according to composition so that data may be extrapolated from one food to other, similar foods in the same category. The International Food Irradiation Project (IFIP) is using this approach in preparing data that it will present to the Expert Committee in 1980 to obtain approval for irradiated foods at doses up to 1.0 Mrd. This represents a clear departure from the US position that irradiation is a food additive and that each food item must be shown by extensive animal studies to be absolutely safe. No foreign country is willing (or perhaps able) to underwrite the expense of the US approach to proving the wholesomeness of irradiated foods.

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Section I.

INTRODUCTION

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1. Preservation of Food by Ionizing Radiation

a. Since the 1940s, the use of ionizing radiation has been studied as a method of preserving foods. Radiation (either gamma rays from a Co-60 or Cs-137 source or beta particles from an electron accelerator) passing through food ionizes some atoms in its path. The macromolecular structure of bacteria, yeasts, molds, insects, nematodes, and other undesirable biological contaminants is altered and results in their destruction. When food atoms are ionized, they suffer no harmful effects. The food does not become radioactive, and with low doses of radiation there is less loss of vitamins than in canning, freezing, or drying. If higher doses of radiation are applied, some vitamin levels decrease.

b. The amount of radiation delivered depends upon the particular food and the results desired. The radiation dose is usually expressed in terms of the rad (rd),[1] defined as that quantity of ionizing radiation that results in the absorption of 10^{-2} joules of energy per kilogram of irradiated material. If the goal is prolongation of shelf life, or storage time, a pasteurization dose, generally from 200 to 500 krd, is sufficient. At even lower doses, radiation can provide effective preservation. A dose of 4-10 krd applied to potatoes or onions is highly effective as a sprout inhibitor. At 20-50 krd, grains and cereals can be disinfested of insects. At 50 krd, sterilization of insect larvae that lodge inside certain fruits is also possible. If the aim is to sterilize food for long-term storage without refrigeration, the required dose is between 2 and 4.5 Mrd.

2. Background of US Effort

a. During the 25-year history of food irradiation research and development (R&D) conducted by the Department of the Army, the United States has generally been considered the world's leader in this field.

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[1] A new unit is being introduced as recommended by the International Organization for Standardization called the gray (Gy). 1 rd=10^{-2} Gy; 1 Gy=1 J/kg. This report will use the rad because of its use in existing documentation. Usage is either the rad, or the rad or gray with the other in parentheses.

The Army, however, has not yet been able to obtain a clearance from the Food and Drug Administration (FDA) to irradiate meats at sterilizing doses of irradiation (>2.5 Mrd), in spite of an expenditure of at least $51 million.

b. The Department of Defense (DoD), dissatisfied with the situation, is considering a number of options; among these are the following: terminating DoD involvement with food irradiation with the submission by 1984 of the petition for radiation-sterilized chicken, offering the process to the US Department of Agriculture (USDA) as a replacement for nitrite, encouraging the USDA to accept responsibility for a National Food Irradiation Program, and terminating the wholesomeness portion of the Army Food Irradiation Program, but maintaining a small technology base effort. The current play (May 1979) is to implement the Government Accounting Office's recommendation;[1] i.e., to complete the wholesomeness studies with irradiated chicken and submit a petition to the FDA based on the results.

[1] PSAD-78-146, The Department of the Army's Food Irradiation Program--Is It Worth Continuing?, Comptroller General of the United States, 29 Sep 1978, pp iii-iv.

Section II.

INTERNATIONAL ACTIVITIES

A. INTERNATIONAL ACTIVITIES BEFORE 1970

1. Scope of Effort

a. Prior to about 1970, the United States was the recognized leader in the field of food irradiation. Other leading countries were the USSR, the United Kingdom, and Canada. At least 50 nations had R&D programs in food irradiation, and 26 other countries planned to institute such programs. (Together, these nations constitute four-fifths of the world's countries.) The two program areas receiving the most attention were sprout inhibition in potatoes and onions and disinfestation of grain, fruits, and dried products; about 25 countries reported work in each of these 2 areas. Other R&D programs receiving major attention were the prolongation of the shelf life of fresh fruits, fish, and meats and the microbiology of irradiated foods. In at least 11 countries, development had reached the stage of pilot plant testing; one country, Canada, had proceeded with commercial application of potato irradiation. (This venture in 1965 ended in failure within a year.) In addition to the United States, at least 14 countries had conducted animal feeding tests, and by the end of 1970 nine countries (USSR, Canada, Israel, Spain, the Netherlands, the United States, the United Kingdom, Uruguay, and Denmark) had obtained some clearances for the use of irradiation in preserving foods for human consumption. The USSR was the first country to issue such a clearance; by 1970, it had approved the greatest number of items (four).[1]

b. Prior to 1970, several other countries besides the United States were conducting research into sterilization doses of irradiation. Italy had experimentally used irradiation to destroy hoof-and-mouth virus in meat; Denmark had studies irradiating spices used in luncheon meat to destroy heat-resistant spores; and the United Kingdom had a basic research program for radiation sterilization of meat.[2]

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[1] ST-CS-01-51-70, Antonelli, G.V., Food Irradiation Technology--Foreign, US Army Foreign Science and Technology Center, Mar 1970, p VII, 1-5, 25, 27.

[2] *Ibid.*, pp 13-18.

2. Effects of US Setbacks on Other National Programs

a. In 1968, to the surprise of the international food irradiation community, the US food irradiation program began to run into difficulties: The Army withdrew the ham petition, and the FDA rescinded the previously approved bacon petition; furthermore, in 1970, the Atomic Energy Commission (AEC)[1] began to terminate its financial support of the US National Food Irradiation Program.

b. As a consequence of the difficulties experienced in the US program, food irradiation programs were cut back worldwide, with the prospect of early termination if the problem of obtaining clearances could not be resolved. Because of the expense, only a few countries were able to carry out the required lengthy wholesomeness[2] testing for each foodstuff. The rest of the countries interested in food irradiation were adopting a wait-and-see attitude. The reputation of the US FDA at this time was such that many countries, especially the developing countries, based their public health regulations on FDA decisions.

B. INTERNATIONAL ORGANIZATIONS

3. International Food Irradiation Project

a. In 1970, resolution of the question of the wholesomeness of irradiated foods became an international effort. It was recognized that the solution to the impasse could be achieved only by international cooperation. This resulted in the creation in October 1970 of the International Food Irradiation Project (IFIP), sponsored by the International Atomic Energy Agency (IAEA), the Food and Agriculture Organization (FAO), and the European Nuclear Energy Agency of the Organization for Economic Cooperation and Development (ENEA/OECD), with 19 contributing member countries. The Project is charged with the following objectives:

- Wholesomeness testing of irradiated foods.
- Research into the methodology of wholesomeness testing.
- Dissemination of information related to wholesomeness testing.
- Assisting the national and international authorities in considering clearances.

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[1] The AEC is now a part of the Department of Energy.

[2] Wholesomeness--safety and nutritional quality.

b. The IFIP is headquartered at the Institut für Strahlentechnologie in Karlsruhe, Germany. Membership fees (there are 24 member countries), totaling about $300 000 per year (1976), are used to finance research in major toxicological laboratories of the world. Member countries have agreed to support the IFIP until 1981. Although it is neither the first nor the only international effort for food irradiation, it has been the most effective in achieving its goals.[1] The IFIP's accomplishments are discussed in subsection C of this section.

4. International Atomic Energy Agency (IAEA)

The IAEA was established in 1957 as an autonomous intergovernmental organization, linked to the United Nations but retaining independence in policy, programming, and budgetary matters. The mission of the agency is to encourage and assist in the practicable utilization of atomic energy for peaceful purposes. The agency is headquartered in Vienna, Austria.

5. Food and Agriculture Organization (FAO) of the United Nations

The FAO, haedquartered in Rome, Italy, is a specialized agency of the United Nations; its main purpose is to help secure improvements in the efficiency of production and distribution of all food and agricultural products. The FAO functions jointly with the IAEA in food irradiation activities, and collaborates with the World Health Organization (WHO).

6. FAO/IAEA Joint Program

a. In 1966, a joint program known as the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture, was established between the IAEA and the FAO to develop and operate a single program to encourage the appropriate usage of nuclear techniques in agricultural production. The Food Preservation Section is responsible for food irradiation activities.

b. The Joint FAO/IAEA Division's major contribution to food irradiation has been the support of the Joint IAEA/FAO/WHO Expert Committee on the Wholesomeness of Irradiated Food, which convened in 1969 to assess initially the wholesomeness of irradiated wheat, potatoes, and onions.

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[1] This is because it is a project with a limited lifetime (initially 5 years with two 3-year extensions) and the IFIP's Director and Scientific Program Committee have managed a program responsive to specific recommendations of the Joint IAEA/FAO/WHO Expert Committees evaluating the wholesomeness of irradiated foods.

c. The following illustration shows the interrelationships between the IAEA, the FAO, and the WHO for coordinating efforts in food irradiation. The advisory groups and committees are used to communicate information and recommendations based on the combined expertise of the committee and group members. During the sixties, expert panels were convened to assess the state-of-the-art of food irradiation and to make recommendations.

7. Regional Organizations

a. Four noteworthy regional organizations have been active in food irradiation during the seventies. The European Society of Nuclear Methods in Agriculture (ESNA), which meets annually, has as one of its main goals the application of nuclear techniques and technology to improve agriculture and food supply in developing countries. Hungary, Poland, Romania, and Czechoslovakia are rather active in this organization (the ninth annual meeting in 1978 was held in Brno, Czechoslovakia). ESNA has a working group for food irradiation under the chairmanship of Dr. J. van Kooij, of the Netherlands, who resigned last year to take up his new post as head of the Food Preservation Section in the Joint IAEA/FAO Division of Atomic Energy in Food and Agriculture. Dr. J. Farkas, of Hungary, has been proposed as Dr. van Kooij's successor. ESNA, at its last meeting, emphasized the need to generate industrial interest in food irradiation processing, and indicated that the practicable application will depend largely on the outcome of the 1980 meeting of the Joint IAEA/FAO/WHO Expert Committee on the Wholesomeness of Irradiated Foods; it is hoped that at this meeting a general recommendation for clearance of food irradiation up to 1.0 Mrd will be made.[1]

b. The Council for Economic Mutual Assistance (CEMA)--established to coordinate economic interests among the USSR, Hungary, Czechoslovakia, Bulgaria, the German Democratic Republic, Poland, Romania, the Peoples Republic of Mongolia, and Cuba--has two permanent committees: one to investigate peaceful uses of atomic energy and the other to coordinate activities among the food industries. These committees monitor research on the wholesomeness of irradiated foods and attempt to exploit the potential for food irradiation technology in member countries.[2] How effective these committees are is questionable,

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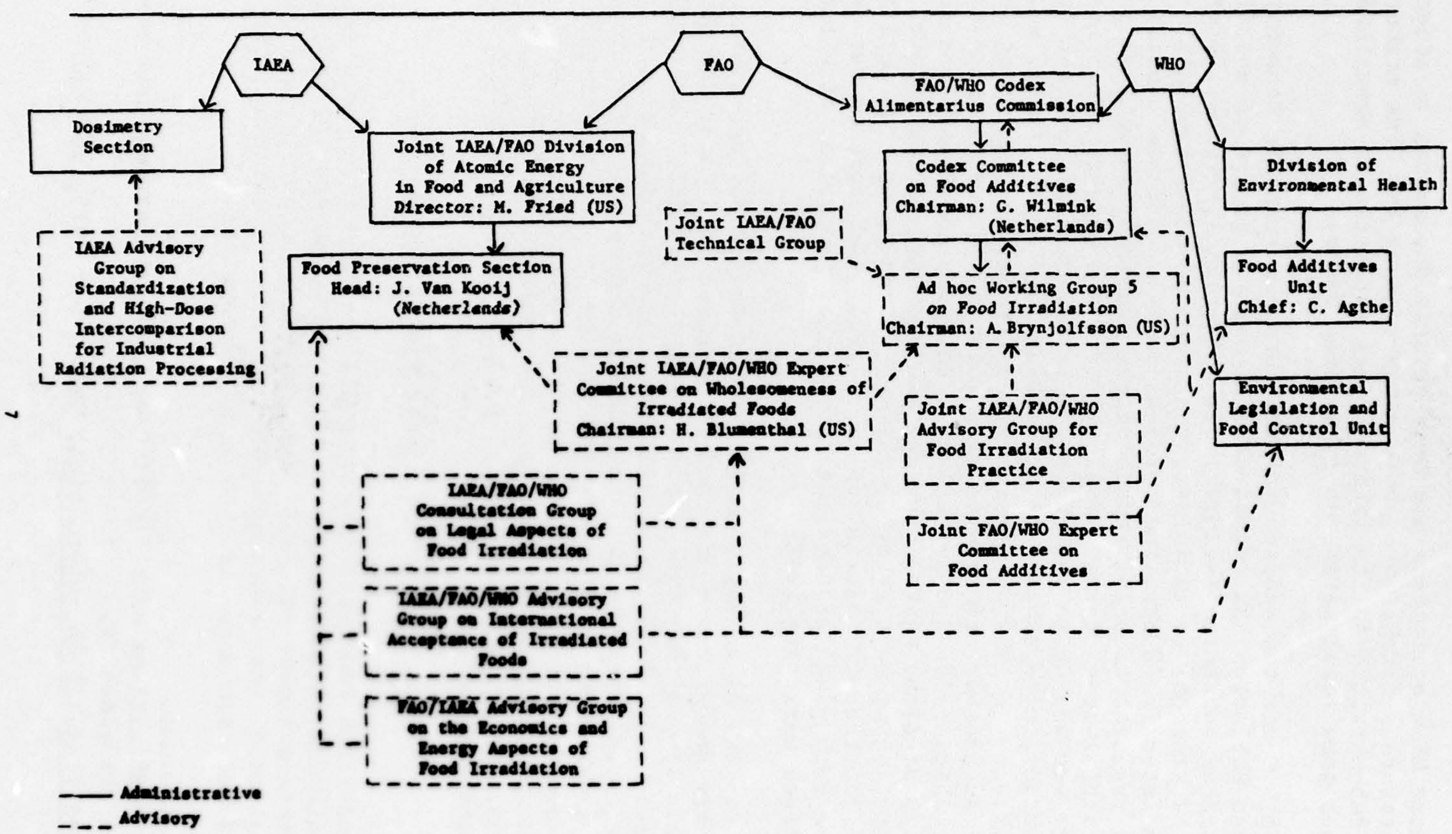
[1] Food Irradiation Information, No. 8, No. 9, No. 4.

[2] Horacek, P., "Useful Radiation: Radiation Processing of Foods," Army Technical and Graphic Monthly, No. 11, Nov 1977, pp 328-330.

Joint IAEA/FAO/WHO Activities for Food Irradiation



because CEMA activities are only briefly documented in accessible literature. Furthermore, only Hungary among the CEMA member countries has demonstrated in its international activities a sustained commitment to the commercialization of irradiated foods.

c. Under the auspices of the European Economic Community (EEC), the Bureau Eurisotop has formed several working groups to coordinate efforts in member countries (Belgium, the Netherlands, France, Germany, and the United Kingdom) to facilitate the simultaneous introduction of certain irradiated foods onto the European market. Efforts consist of laboratory research to solve technological problems, as well as performing industrial-level tests. These efforts are modest. The first working group was set up in 1969 to study irradiation of potatoes to inhibit sprouting, with subsequent processing into chips, fries, and dehydrated potatoes. In 1972, a working group for pasteurization of shrimp, as well as another effort with radicidation[1] of frozen and dehydrated eggs, were initiated. The Netherlands, Belgium, and France conducted the shrimp studies, whereas the egg project was a joint effort, with participation by a majority of the member countries. No activities have been reported from Eurisotop since 1974, although, as far as is known, there were plans to continue the studies initiated, with the goal of eventual marketing tests.[2]

d. The Asian Regional Project on Radiation Preservation of Fish and Fishery Products was launched in November 1973 under the auspices of IAEA. It was the first project initiated under the Regional Cooperative Agreement for Research, Development, and Training Related to Nuclear Science and Technology. The scientific program of the project, planned for a duration of about 5 years, called for the irradiation of sun-dried and smoked fish for the purpose of disinfestation, as well as radicidation and radurization to extend the shelf life of fresh, cooked, semi-dried, and dried fish. Progress on the project's effort has not been reported recently.

C. INTERNATIONAL ACTION

Irradiation preservation must still overcome three hurdles: (1) The resolution of questions concerning wholesomeness, (2) the establishment of international standards and legislative controls, and (3) the identification of the market situation in which irradiation will satisfy a need more economically than present practices.

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[1]For definitions of radicidation, radappertization, and radurization, see the glossary.

[2]Food Irradiation Information, No. 4, Mar 1975, pp 8-10.

8. Wholesomeness

a. The question of the wholesomeness of most food products irradiated at doses of $\leq$1.0 Mrd probably will be resolved within 5 years, if not sooner. The IFIP has been extremely successful in coordinating international research and testing to provide the necessary wholesomeness data for evaluation by the Joint IAEA/FAO/WHO Expert Committee on the Wholesomeness of Irradiated Foods. This Committee, at its 1976 meeting, concluded that irradiated potatoes, wheat, chicken, papaya, and strawberries should be recognized as unconditionally safe for human consumption. Favorably impressed with the data on rice, onions, and fish, the Committee recommended that these foods be given provisional approval pending the results of ongoing studies. Thus, five foods (with a wide variation in chemical composition) were recommended for unconditional approval and three foods for provisional approval. These recommendations, which represent a crucial breakthrough in the development of food irradiation as a practicable method for preserving food, have given a much needed impetus to many national irradiation programs. (Prior to this event, a noticeable pessimism had developed in many countries, and if the Expert Committee had reached a negative verdict the majority of research programs would most likely have been abandoned.)

b. While the recommendations of the Expert Committee are not binding on national health authorities, they have considerable influence on local evaluations of the wholesomeness of irradiated food.[1] For instance, South Africa responded by unconditionally clearing papayas, onions, chicken, mangoes, potatoes, strawberries, and garlic irradiated at various doses up to 700 krd. Dried bananas and avacados were approved for test marketing. In August 1977, France issued temporary acceptances for the irradiation of onions, garlic, and shallots; in November 1976, Czechoslovakia approved testing of irradiated potatoes, onions, and mushrooms; and in April 1977 Hungary issued another approval for a market test of irradiated onions. (See appendix I for a general survey of irradiated food products cleared for human consumption in different countries.)

c. Another important contribution made by the Expert Committee at its 1976 meeting was the assessment that food irradiation is a physical process for treating foods, rather than a food additive,[2] and, that as

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[1]Basson, R.A., and P.S. Elias, "Chemiclearance Goes International," Nuclear Active, Jul 1978.

[2]In the United States, the Food Additives Amendment of 1958 included food irradiation in the definition of food additives.

such, irradiation is comparable to the heating or freezing of food for preservation. This assessment encouraged health authorities to change their approach to the toxicological evaluation of the wholesomeness of irradiated foods. The Expert Committee determined that it was impracticable to exaggerate the feeding levels of irradiated foods in animal studies beyond a modest degree and inappropriate to exaggerate the radiation dosage much beyond that used in practice. Either of these practices gives rise to effects that are irrelevant to the toxicological potential of irradiated food.[1]

d. The Expert Committee at its 1976 meeting also opened the way for the chemiclearance approach to demonstrate the wholesomeness of irradiated foods. The Committee was presented with evidence on the great similarity in radiolytic products in related foods treated with radiation doses of 1 Mrd, and agreed with the view that evidence of the safety of one form of irradiated food could be applied to other forms of the same food.[1]

e. With recognition that radiation chemical data were increasingly important in the ultimate objective of obtaining clearances for all foods, the IFIP began organizing a coordinated program designed to provide the kind of chemical data that will meet the requirements for the September 1980 meeting of the Joint IAEA/FAO/WHO Expert Committee for the Wholesomeness of Irradiated Food. The IFIP's CORC-program (Co-Ordinated Radiation Chemistry) hopes to provide the connecting link between those foodstuffs that have been thoroughly tested in animal feeding studies and shown to be safe and the much larger group of foodstuffs that have not yet been tested. The CORC-program consists of 20 projects being carried out in 12 laboratories from 7 countries. Two coordination meetings are held at IFIP headquarters every year to maintain direction and impetus until the fifth meeting in the first half of 1980, when position papers summarizing the data that have been obtained since the 1976 meeting will be drawn up for the 1980 Joint IAEA/FAO/WHO Expert Committee meeting.[2]

f. The IFIP also has been sponsoring since 1976 in-house research directed at developing methodology for short-term testing of irradiated foods. Mammalian cell culture techniques for screening of possible

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[1]Report of a Joint IAEA/FAO/WHO Expert Committee, "Wholesomeness of Irradiated Food," Technical Report Series 604, World Health Organization, Geneva, 1977, pp 8-11.

[2]Basson, R.A., and P.S. Elias, *op. cit.*

carcinogenic or mutagenic compounds have been studied to provide alternative evidence of safety to the traditional animal feeding studies. The IFIP, noting that no single, short-term test system will be acceptable for assessing genetic risks to man, is planning studies using other indicator organisms, such as bacteria and insects.[1]

g. The IFIP believes the best approach to the wholesomeness question is a judicious balance between animal bioassays, short-term screening tests, and supportive radiochemical data.[1]

9. International Legislative Controls

a. So far, legislative actions have been concerned with granting clearances for individual foods at the national level (see appendix I). The need for international alignment of the relevant national standards to permit international trade in irradiated foods has been widely recognized, however. With the recommendations for acceptance (including conditional acceptance) of eight foods by the Joint IAEA/FAO/WHO Expert Committee, the Codex Alimentarius Commission, which is responsible for the Joint FAO/WHO Food Standards Program, has advanced a general standard for the irradiation of the eight foods and a Code of Practice for the Operation of Radiation Facilities Used for the Treatment of Foods to step 8 of the Codex Standards Procedure. In December 1979, the Codex Alimentarius Commission is expected to adopt the food irradiation standard for the eight aforementioned food products and to adopt the code of practice as the recommended standard for the 114 member countries of the Commission. The major portion of irradiated products to be accepted and included in the Irradiated Foods General Standard by the Codex Alimentarius will be taken up at the 1981 meeting of the Commission, after a general recommendation by the 1980 Joint IAEA/FAO/WHO Expert Committee on the Wholesomeness of Irradiated Foods. Because Codex Commodity Standards are designed to permit worldwide trade, this is regarded as the best means of attaining acceptance of irradiated foods as items of international trade. While there appears to be a lot of "ifs" in the above scenario, the prospects for international clearance and standardization are considered very good.

b. To implement international trade in irradiated foods, not only is standardization required but a legal framework that will serve as a basis for harmonizing national legislation and regulatory procedures is necessary. Countries trading in irradiated foods need the assurance that foods irradiated in one country and offered for sale in another

[1]"Short-Term Tests Being Applied to Food Irradiation," Food Chemical News, Mar 19, 1979, pp 6-9.

country have been subjected to commonly acceptable standards of wholesomeness, hygienic practice, and irradiation treatment control. This is extremely important, because it is not possible analytically to determine that a food has been irradiated, much less in accordance with an approved treatment process. Model regulations have been prepared by a Joint IAEA/FAO/WHO Advisory Group on International Acceptance of Irradiated Foods, which met in November 1977 to consider the legal aspects. Included in the model regulations are control of irradiation facilities, control of food irradiation, and control of trade in irradiated food. The Advisory Group recommended that IAEA/FAO/WHO promulgate model regulations for its member states.

c. A large increase in industrial applications is expected as soon as irradiated foods are cleared for international trade via the Codex Alimentarius Standards Program, and their legislative control is approved among trading countries.

10. Commercialization

a. Pilot-plant-scale, and a limited number of commercial, activities have either been developed or are in progress in several countries; these activities are described in section III and are summarized in appendix II. There have been rumors of some international trade, but no country is ready to admit this activity is taking place until international clearances and standards exist. Technological and economic feasibility studies of the practicable application of the irradiation process on various food items have either been done or are in progress in Japan, South Africa, Hungary, Italy, the Netherlands, France, Belgium, Germany, and the United States. These studies correlate closely with respective national clearances.

b. To assist in the commercialization of irradiated foods in developing countries, the Joint FAO/IAEA Division of Atomic Energy in Agriculture is supporting a coordinated research program concentrated in the following areas:

- The technological and economic feasibility of the radiation preservation and sanitation of fruits, vegetables, grains, and condiments.
- The preservation of dried fish and fishery products.
- The wholesomeness of the food irradiation process.

The Division is planning pilot-scale studies on the technological and economic feasibility of food irradiation in developing countries, which

will be carried out at the International Facility for Food Irradiation Technology (IFFIT). The IFFIT, funded by the FAO, the IAEA, the Government of the Netherlands, and contributing member states of FAO and IAEA, is being established at Wageningen. The mission of the Facility is to bridge the gap between research and commercial application by providing in-plant training of personnel, especially from developing countries, in the field of food irradiation. The Facility will thereby help to insure proper preparation of irradiation facilities in conformity with the Codex Standard for Irradiated Foods and the Code of Practice for the Operation of Radiation Facilities Used for the Treatment of Foods.

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Section III.

NATIONAL DEVELOPMENTS

1. Overview

a. At least 50 countries have programs for the preservation of food by irradiation. These countries, distributed throughout the world, range from the highly industrialized nations to countries struggling to feed their ever-increasing populations. Countries known to have active food irradiation programs are listed in appendix III, which shows the food commodities under investigation in each country.

b. European countries, Japan, and certain less developed countries are making significant progress toward the realization of irradiation as a food preservation process. This irradiation, however, is limited to doses of less than 1.0 Mrd, and is done primarily to extend shelf life by the destruction of pathogens and molds, by disinfestation, and by inhibition of sprouting or maturation. In 1968, only six foods had been granted final approval for irradiation, by a total of four countries. Ten years later, 15 foods had been cleared in a total of 13 countries (see table).

c. The less developed countries are increasing their participation in international food irradiation activities. Since 1976, India, Iraq, and Ghana have joined the IFIP. Nigeria and Uruguay have acquired modestly equipped facilities, whereas in 1968 they had none (neither country, however, has become a member of the IFIP). In 1970, Uruguay granted a clearance for irradiated potatoes. The research conducted in developing countries appears to be directed primarily toward the preservation of food for export rather than for internal consumption. As in the developed countries, food irradiation will become a reality in the less developed countries only if it is commercially or economically advantageous.

2. Foreign Food Irradiation Programs

a. In most countries, food irradiation programs are organized and funded within the structure of atomic energy rather than within agriculture and food organizations, although, of course, the latter implement the programs. Whether this situation may be impeding the use of irradiation technology for food processing in those countries that have issued clearances for irradiating certain foods cannot be determined. Generally, increasing layers of bureaucracy tend to slow the introduction of new technology.

b. Most countries showing an interest in food irradiation do so for potential economic gain, although there are contradictions. The

Progress in Obtaining Clearances of Irradiated Foods for Human Consumption

	By 1968	By 1975
Countries issuing clearances	Canada Israel USSR US	Canada Israel USSR US Uruguay Thailand Spain South Africa Philippines Netherlands Japan Italy Denmark
Products approved	Onions Potatoes Dry food concentrates (for mush, gruels, puddings) Dried foods Grains Wheat and wheat flour	Onions Potatoes Dry food concentrates (for mush, gruels, puddings) Dried foods Grains Wheat and wheat flour Mushrooms Chicken Fish fillets (cod or plaice) Papayas Mangoes Strawberries Garlic Hospital food for sterile diets

United Kingdom claims to have no need for food irradiation, yet it continues to support international efforts and send experts to international meetings; in contrast, Australia, which has much to gain, has almost ceased to participate in international meetings.

c. In several countries, the military has expressed interest in food irradiation processing, but no funding by the military of food irradiation programs is known to have occurred. One reason for this is probably the lack of programs for radiation sterilization of food. The other, more important, reason is that the military in the majority of countries funds little, if any, food research. Iran is the only other country besides the United States in which the military has had "an association" with a food irradiation program. If Iran's food irradiation program survives the recent political changes, the military will almost certainly not be involved with the program.

3. Significant Food Irradiation Activities in Free World Countries

Four countries among the highly industrialized nations show evidence of either commercialization of irradiation processing of food or being very near to beginning commercial operations. They are Japan, South Africa, the Netherlands, and Italy. Their programs are summarized in the following paragraphs.

a. Japan. At least 30 Japanese universities and institutes have conducted research in the field of food irradiation. Since 1967, research on food irradiation has been designated as the Atomic Energy Specified Comprehensive Research Program for preventing loss of food supplies and for stabilizing food distribution. Under this project, the Taskasaki Radiation Chemistry Research Establishment of the Japan Atomic Energy Research Institute, Tokyo, has been in charge of pilot-scale development and fundamental research.

Following the unconditional clearance in August 1972 to allow irradiation of potatoes to inhibit sprouting, an industrial-scale irradiation plant, with a capacity for irradiating 10 000 tonnes per month, was constructed during 1973 at the Shihoro Agricultural Cooperative Association in Hokkaido. Although this plant has received a wide acclaim as the first successful commercial operation, it was in fact highly subsidized by the Japanese Government.

The plant commenced operation on 12 January 1974. Production plans called for the following amounts of potatoes to be irradiated: 15 000 tonnes in 1973-74, 19 000 tonnes in 1974-75, 21 000 tonnes in 1975-76, and 30 000 tonnes in 1976-77. The irradiated potatoes were marketed in Tokyo, Osaka, and Hokkaido. Nearly 50% were not marketed, but were processed into starch. It is hoped that the operation can be made more cost effective by processing irradiated potatoes into potato chips and french fries. There may be plans to make this a multipurpose facility in the event an unconditional clearance is granted for onions.

Japan is accomplishing good basic research, and has the governmental support necessary to subsidize irradiation facilities until such time as they become cost effective to be self-sufficient commercial operations. The Japanese have shown great interest in using irradiation to extend the storage life of food products up to 1 year. There is no indication, however, that they are interested in irradiation to achieve sterilization and long-term storage.

b. South Africa. The two organizations conducting the most food irradiation research in South Africa are the South African Atomic Energy Board, which directs the operation of the National Nuclear Research Center at Pelindaba, and the Research Institute for Fruit and Food Technology at Stellenbosch. In addition to these two facilities, a Co-60 pilot plant operated by the Letaba Cooperative Ltd. for the treatment of subtropical fruits was constructed at Tzaneen. The plant irradiates food in sufficient quantities for commercial testing and evaluation.

During 1975-78, marketing tests with several products were conducted. In 1975, a small consignment of irradiated mangoes was shipped to the Netherlands for evaluation. A second shipment, 1800 trays of Kent mangoes, was sent to the Netherlands in February 1977. Approval for retailing 50 tonnes of irradiated mangoes had been obtained from the Dutch authorities based on a similar clearance by the South African Department of Health to sell the same quantity in South Africa. Upon arrival of these mangoes in the Netherlands, 79% of the batch was acceptable, compared with only 20% of the nonirradiated control. Following approval of the unlimited clearance in August 1978, a 3-month consumer acceptance trial with 4 tonnes of irradiated mangoes took place in two major cities.

Following similar clearances granted in August 1978, 4 tonnes of papayas, 4 tonnes of strawberries, and 60 tonnes of potatoes were irradiated and test marketed to determine the level of consumer acceptance.

South Africa has one of the more progressive programs to obtain approval of irradiated foods. Irradiation will supplement existing preservation methods, which will expand South Africa's export market in perishable commodities. Because South Africa is a highly industrialized country and has one of the more efficient food distribution systems in Africa, irradiation processing will also enable it to expand its local markets. It was reported in late 1978 that irradiated foods will soon be available for sale to the public.

c. <u>The Netherlands</u>. The major research center for food irradiation in the Netherlands is the Institute for Atomic Sciences in Agriculture[1] (ITAL) at Wageningen. A multipurpose Co-60 gamma radiation pilot plant for food irradiation[2] was constructed in this city in 1966. This pilot-scale facility was financed jointly by the government and private industry. Since a reorganization in 1972, the operation of the pilot plant has been consolidated under the control of ITAL. The main objective of the operation of this plant is to determine the economic feasibility for irradiating foods by conducting marketing trials.

Extensive marketing trials have been conducted with many types of irradiated foods. In 1973, Arnhem housewives had the opportunity to assess radiation-pasteurized chicken. Approximately 40% of the sample group was willing to buy irradiated fresh chicken, and 20% preferred the irradiated to unirradiated poultry. In another test, fresh irradiated broilers were distributed to four hospitals and a home for the elderly and evaluated by the dieticians. A small-scale trial was carried out with 10 tonnes of irradiated fish fillets and 5 tonnes of shrimp. This project was a joint effort of ITAL and the Institute for Fishery Products.

During September 1974, the Netherlands took part in a Bureau Eurisotop program to study the effects of irradiation on brown shrimp. Brown shrimp were peeled and packed in the Netherlands under supervision of the Institute for Fishery Products, Ijmuiden. They were then irradiated at the pilot plant in Wageningen, and transported under refrigeration to Karlsruhe, Germany. This resulted in a prolongation of the shelf life and a reduction in the total microbial count of the shrimp.

The following irradiated foods have received unlimited clearances from the Ministry of Public Health and Hygiene and the Ministry of Agriculture and Fisheries: mushrooms, potatoes, shrimp, onions, chicken, fish fillets (cod or plaice), and prepackaged peeled potatoes. Irradiated deep-frozen meals for hospital patients will receive unlimited clearances as the need arises. Numerous foods have been granted limited clearances for test marketing or as experimental batches.

The Netherlands has the most progressive program in food irradiation and development. Clearances have been granted for more types of irradiated foods than any other country. If international standards and legislation are approved, commercialization of irradiated foods will provide greater distribution locally and also expand the Netherlands' export market.

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[1]Stichting Instituut Voor de Toepassing Van Atoomenergie in de Landbouw.
[2]Stichting Proefbedrijf Voedelbestraling.

d. Italy. The Comitato Nazionale per l'Energia Nucleare (CNEN)[1] administers Italy's nuclear energy program. The organization under CNEN that conducts food irradiation research is the Laboratorio per la Applicazioni in Agricoltura.[2] The irradiation experiments are carried out at the Centro Studi Nucleari della Cassucia (CSN)[3]. The Italian National Nutrition Institute also conducts food irradiation experiments, using the facilities of the CNEN laboratories. In addition to these existing facilities, a government-financed industrial-scale pilot plant is slated for completion in late 1980, which will carry out 3-year research programs on potatoes, onions, carrots, and animal feed.

It was reported in 1975 that in addition to existing governmental facilities two private firms had their own irradiation facilities and were conducting research and commercializing various types of irradiated products. The two companies, Gammatron s.p.a. and Gammarad Italia, were conducting feasibility studies for the preservation of fruits, vegetables, and sausages.

Unlimited clearances were granted on August 30, 1973, for the consumption of irradiated potatoes, onions, and garlic. Following the approval of these clearances, marketing trials were carried out in March 1976 using 15 tonnes of irradiated potatoes. This market test was a joint effort of the Fucino Agency and the Marsica Cooperative. The potatoes were irradiated at the Applied Radiation Division of the Casaccia Nuclear Center and stored for 2 months prior to marketing in Rome, Bologna, and Pescara. The consumers exhibited a marked preference for the irradiated potatoes with respect to the quality.

Italy appears to be firmly committed to the food irradiation program. Great interest has been expressed by private industry to process irradiated potatoes into various types of potato products. Both governmental approval of funds for the multipurpose irradiation plant and the ongoing wholesomeness tests are significant indicators that Italy has the capability for large-scale commercialization of irradiated foods.

4. Selected Food Irradiation Activities in Developing Countries

Iraq, Thailand, and Egypt show the most promise among the developing countries of marketing irradiated foods. Iraq is interested in irradiating a single commodity--dates. Thailand suffers extensive onion crop

[1]National Nuclear Energy Commission.

[2]Laboratory for the Application of Atomic Energy to Agriculture.

[3]Casaccia Nuclear Study Center.

losses and has to import nearly 1000 tonnes to meet local needs in the off-season. Egypt has a broad irradiation research program concerned with fruits, vegetables, and meats. Activities in these countries are summarized in the following paragraphs.

a. Iraq. Irradiation research is carried out at the Nuclear Research Institute in Baghdad. The radiation preservation of dates, using mild heat plus low doses of irradiation, is important to Iraq's exploitation of international markets. Doses as low as 10-90 krd prolong the ripening process considerably, while a 50-krd dose is sufficient to disinfest the dates at all stages of insect development.

Iraq joined the IFIP as a full member July 1, 1975. Funds were approved by the Scientific Programme Committee of the IFIP for Iraq to conduct short-term animal feeding studies on the wholesomeness of dried dates. The Nuclear Research Institute of Iraq is supplying both the irradiated and nonirradiated dates for the study.

As a result of Iraq's large contribution to the IFIP and the favorable results received from the irradiation studies on dates, a potential for commercialization is believed to exist.

b. Thailand. The Office of Atomic Energy for Peace (OAEP), Bangkok, is responsible for conducting food irradiation research in Thailand. An economic feasibility study to irradiate onions was conducted because of Thailand's estimated 50% onion crop loss due to sprouting and rotting. The price of onions as a result fluctuates greatly throughout the year due to the high cost of importing onions, plus a government-levied import tax of US $250 per tonne. Subsequently, from 1970 to 1972 the OAEP carried out a research program to determine the effects of gamma irradiation on the sprouting of onions. Irradiation of onions about 15 days after harvesting and then storage at 10°-$12^{\circ}C$ resulted in a negligible amount of sprouting. Based on this research, in March 1973, the Ministry of Public Health granted an unlimited clearance for consumption of onions irradiated at doses of 10 krd.

Several onion-trading firms in Bangkok were highly interested in the experimental research being conducted. In 1973, one firm planned to irradiate 100 tonnes of onions to investigate the commercial potential for this process. Another firm requested authorization from the OAEP to irradiate 300 tonnes of onions in the spring of 1974.

In light of the clearance and the interest expressed by private industry, wide-scale commercialization of irradiated onions seems promising, and may be taking place.

c. Egypt. In 1972, the Egyptian Academy of Scientific Research and Technology formed a National Committee for Radiation Preservation of Food to coordinate food irradiation research and development between a number of organizations. Since 1974, the National Center for Radiation Research and Technology (NCRRT) has been carrying out six research projects financed by the Academy of Research and Technology.

Extensive research has been conducted on irradiation of various types of fruits and vegetables. This is vitally important, since Egypt is known for its large fruit and vegetable production for local consumption and for export to Arab, European, and African countries. The NCRRT initiated an extended pilot-scale research program on sprout inhibition in potatoes and onions, with special emphasis on the susceptibility of irradiated foodstuffs to fungal infection.

Egypt has also expressed interest in using irradiation to preserve meat, poultry products, and fish. A minimum dose of 1.5 Mrd results in a 4-week shelf life for chicken under refrigeration. Pasteurization doses of gamma radiation have extended the shelf life of lamb meat and sausages up to 45 days under refrigeration at 1^{o}-2^{o}C. The NCRRT was involved in research studies on the radiation preservation of fish from Lake Karoun, Lake Nasser, and the Nile River.

From 1974 to 1977, short-term wholesomeness studies were conducted on potatoes, stored grains, broad beans, wheat, corn, and rice. Recently the NCRRT has been conducting an extensive research program to assess the safety of irradiated meat. Further applications may include a test program to evaluate the wholesomeness of certain foods; e.g., potatoes, onions, and garlic receiving a combined treatment.

No irradiated food products have received clearances for human consumption in Egypt. Egypt seems to be moving to formulate its own policy regarding radiation preservation of food independent of other countries. Various economic and technical problems remain to be resolved before the commercialization of irradiated foods can be implemented. The high percentage of food losses due to spoilage, however, justifies the utilization of more efficient means of food preservation. Food irradiation is viewed as an important advancement in food preservation; because thermal processed foods have not found wide acceptance in Egypt, sufficient refrigeration is not available, and there is rising public opinion against the use of food additives. If international standards for irradiated foods are adopted, this will enable the Egyptians to increase their export market.

5. Significant Food Irradiation Activities in European Communist Countries

Three Eastern European Communist countries have shown a commitment to food irradiation processing: the USSR, Czechoslovakia, and Hungary. The very extensive Soviet food irradiation research program is in a state of limbo. What the problem is with the Soviet effort can only be speculated. The Soviet's need for irradiation food preservation is great, because their food distribution system is so poorly managed that much food is held in storage until it spoils. The Hungarians have been very active in international food irradiation efforts, and have conducted an excellent, widely respected research program; however, they have not issued any final clearances yet for irradiated foods. The Czechoslovak efforts have only become visible since 1976. The programs in these three countries are discussed in greater detail in the following paragraphs.

a. USSR. The Soviets have conducted food irradiation research for nearly 25 years. During the 1960s, a great amount of research was conducted that almost matched the US level of effort. Leading institutes for research and development of irradiated foods in the USSR are the All Union Scientific Research Institute of the Canning and Vegetable Drying Industry (VNIIKOP), the Moscow Technological Institute of the Meat and Dairy Industry, and the All Union Scientific Research Institute of the Meat Industry (VNIIMP). The Institute of Nutrition of the Academy of Medical Sciences is responsible for insuring the wholesomeness of irradiated foods.

The USSR was the first country to issue clearances for any irradiated foods, beginning with potatoes in 1958. By 1968, the Soviets reported that they were planning facilities for commercial production of irradiated foods. It was reported, however, at an All-Union seminar held in the USSR in June 1974 that mass production of irradiated foods had not occurred, although a total of 800 irradiation devices reportedly existed in 140 food research laboratories and industrial facilities.

By the early 1970s, it was evident that the Soviets had terminated their radiation sterilization program. Besides the technical problems the Soviets had with irradiating meats at doses >1.0 Mrd, they found in their wholesomeness studies metabolic effects in rats fed precooked beef irradiated at 0.8 Mrd. They have continued during the 1970s additional wholesomeness studies, including animal feeding trials and studies for mutagenic activity, on foods previously approved for human consumption.

It was reported in August 1978 that a production-scale experiment irradiating grain was conducted by the Institute of Nuclear Physics of

the Siberian Department of the USSR Academy of Sciences. An electron accelerator was installed at the grain elevator of the Siberian Branch of the All-Union Scientific Research Institute of Grain, which successfully processed more than 100 tonnes of grain per hour. An industrial-scale capability exists for irradiating grain; however, it has not been implemented to date.

According to all available sources, the Soviets are not industrially processing irradiated foods. While the wholesomeness question may be a partial explanation for this shortcoming, the Soviets are suspected to be having great difficulty moving from pilot-scale production to full-scale industrial production. This is one of their chronic problems in many industries, and is especially true in the food industry, which has an overall low funding priority for capital expansion. Because there still is reservation on the part of some influential scientists regarding the wholesomeness of irradiated foods, the classic hurdle described above will not be overcome soon. Only an unequivocal high priority go-ahead, sufficiently funded, will produce irradiated foods for mass consumption.

The foods probably closer to being marketed in terms of completed technology, wholesomeness and market testing, economic evaluation, and clearances from health authorities are potatoes and onions irradiated at low doses.

b. Czechoslovakia. Czechoslovakia is one of the primary eastern European leaders conducting research and market testing of irradiated foods. Pilot-plant studies, under the auspices of the Czechoslovak Atomic Energy Commission, were initiated in 1976 as part of their present 5-year economic plan. The Nuclear Research Institute, Řež, equipped with a Co-60 source, carries out the irradiation for the pilot-plant experiments.

Since 1976, Czechoslovak research has been concentrated on those food commodities suitable for processing in Czechoslovakia; i.e., potatoes, onions, and mushrooms. Further investigation has been suspended on grain, meat, and meat products due to unfavorable results from both the economic and technological point of view.

Based on recommendations of the Joint IAEA/FAO/WHO Expert Committee on the Wholesomeness of Irradiated Food and on the results of the Center for Food Hygiene and Nutrition of the Institute of Hygiene and Epidemiology, potatoes, onions, and mushrooms received a 3-year clearance in late 1976. A petition has also been submitted for a clearance to be granted for strawberries.

Several commercial storage tests and consumer trials were conducted during 1976 and 1977 on irradiated potatoes, onions, and mushrooms. The first consumer trials with irradiated food took place in June 1976. Approximately 500 kg of irradiated potatoes were test marketed, and all but a small percentage of people preferred the irradiated potatoes to the chemically treated ones. A large consumer education campaign, concerning the purpose and advantages of food irradiation, was conducted prior to the marketing test. Subsequently, 7 tonnes of potatoes irradiated for commercial storage tests in late 1976 and early 1977 showed no evidence of sprouting or shrinking. The irradiated potatoes exhibited a higher sensitivity to rotting, and low ratings were received due to the uneven color.

Oyster mushrooms appeared suitable for commercial production; however, the large quantity of spores released while being transported and the allergic reactions by the handling personnel will prohibit any increase in production.

Czechoslovakia's acceptance of the Joint IAEA/FAO/WHO Expert Committee's approval of various food products is a promising indication that irradiated foods will be commercialized. It will be necessary, however, to validate laboratory results with pilot-scale production tests before the technology can be industrialized.

c. Hungary. The two facilities conducting most of food irradiation research in Hungary are the Central Food Research Institute and the Isotopic Research Institute of the Hungarian Academy of Sciences, both located in Budapest.

No irradiated food has received an unconditional clearance; however, numerous test marketing studies have been conducted on potatoes, onions, and strawberries. Experimental batches have also been approved for the use of an irradiated spice mixture in sausages.

The Ministry of Food and Agriculture granted permission for 200 tonnes of potatoes to be irradiated in 1971 with a maximum dose of 15 krd. Forty-five tonnes of potatoes were irradiated at the pilot plant of the Central Food Research Institute and marketed in 1972. An additional approval was granted for 10 000 tonnes to be sold during 1973 and 1974.

Extensive marketing tests have been conducted with irradiated onions. Two tonnes of onions were cleared for consumption on April 21, 1976, and marketed in green grocery shops of the Vegetable and Fruit Marketing Cooperative Enterprise. During 1977, the Hungarian authorities granted an additional clearance for 2 tonnes of irradiated onions,

which were marketed in three shops in Szeged. Subsequently, 40 tonnes of onions were irradiated in September 1977 and marketed in May 1978 in five towns, including Budapest and Szeged.

An economic feasibility study has been conducted to determine the cost effectiveness of irradiating potatoes and onions on a commercial scale. A technical analysis indicated that the cost of investing in an irradiator capable of treating the total amount of potatoes and onions consumed in Budapest could be recouped in 5 years.

In 1973, marketing trials were carried out on strawberries under the auspices of the Budapest Vegetable and Fruit Marketing Cooperative. Strawberries irradiated with either 100 krd or 200 krd sold twice as well as the unirradiated ones.

Consumer acceptance studies have resulted in favorable responses from merchants and the public alike. Although Hungary has conducted repeated surveys on several food products, no foods have received unconditional clearances. Perhaps Hungary is awaiting the promulgation of international standards by the Codex Alimentarius before issuing its own clearances and proceeding with commercialization of irradiation processing.

APPENDIX I.

GENERAL SURVEY OF IRRADIATED FOOD PRODUCTS CLEARED FOR HUMAN CONSUMPTION IN DIFFERENT COUNTRIES[1] (AS OF DECEMBER 1978)

Country (Organization)	Product	Purpose of Irradiation	Type and Source of Radiation			Dose (krd)	Date of Approval
			Co-60	Cs-137	Electrons		
Bulgaria	Potatoes*	Sprout inhibition	+				1971
	Potatoes*	Sprout inhibition	+			10	30 April 1972
	Onions*	Sprout inhibition	+			10	30 April 1972
	Garlic*	Sprout inhibition	+			10	30 April 1972
	Grain*	Insect disinfestation	+			30	30 April 1972
	Dry food concentrates*	Insect disinfestation	+			100	30 April 1972
	Dried fruits*	Insect disinfestation	+			100	30 April 1972
	Fresh fruits* (tomatoes, peaches, apricot, cherry, raspberry, grapes)	Radurization	+			250	30 April 1972
Canada	Potatoes	Sprout inhibition	+			10 max	9 November 1960
						15 max	14 June 1963
	Onions	Sprout inhibition	+			15 max	25 March 1965
	Wheat, flour, whole wheat flour	Insect disinfestation	+			75 max	25 February 1969
	Poultry****	Radicidation (Salmonella)	+			700 max	20 June 1973
	Cod and haddock fillets****	Radurization	+			150 max	2 October 1973
Chile	Potatoes* ****	Sprout inhibition	+				31 October 1974
Czechoslovakia	Potatoes* ****	Sprout inhibition				10 max	26 November 1976
	Onions* ****	Sprout inhibition				8 max	26 November 1976
	Mushrooms* ****	Growth inhibition				200 max	26 November 1976

[1]References: Food Irradiation Newsletter, Vol. 1, No. 3, November 1977, pp 34-39, and Vol. 2, No. 1, March 1978, p 45; Food Irradiation Information, No. 9, December 1978.

Country (Organization)	Product	Purpose of Irradiation	Type and Source of Radiation			Dose (krd)	Date of Approval
			Co-60	Cs-137	Electrons		
Denmark	Potatoes	Sprout inhibition			10 MeV	15 max	27 February 1970
France	Potatoes**	Sprout inhibition	+			7.5-15	8 November 1972
	Onions**	Sprout inhibition	+	+		7.5-15	9 August 1977
	Garlic**	Sprout inhibition	+	+		7.5-15	9 August 1977
	Shallots**	Sprout inhibition	+	+		7.5-15	9 August 1977
Federal Republic of Germany	Deep-frozen meals* ***	Radappertization	+			2500-4500	24 March 1972
	Potatoes*	Sprout inhibition	+			15 max	26 September 1974
Hungary	Potatoes****	Sprout inhibition	+			10	23 December 1969
	Potatoes****	Sprout inhibition	+			15 max	10 January 1972
	Potatoes****	Sprout inhibition	+			15 max	5 March 1973
	Onions****	Sprout inhibition	+			15 max	5 March 1973
	Onions****	Sprout inhibition					21 April 1976
	Onions****	Sprout inhibition	+			6	6 August 1975
	Onions****	Sprout inhibition					6 September 1976
	Strawberries****	Radurization	+				5 March 1973
	Additive to canned luncheon meat**** (wheat flour, powdered garlic, sodium caseinate, powdered onions, ground paprika)						20 November 1976
	Mixed spices* (black pepper, cumin, paprika, dried garlic: for use in sausages)	Radicidation	+			500	2 April 1974
	Onions****	Sprout inhibition				15 max	April 1977
Israel	Potatoes	Sprout inhibition	+			15 max	5 July 1967
	Onions	Sprout inhibition	+			10 max	25 July 1968

Country (Organization)	Product	Purpose of Irradiation	Type and Source of Radiation			Dose (krd)	Date of Approval
			Co-60	Cs-137	Electrons		
Italy	Potatoes	Sprout inhibition	+			7.5-15	30 August 1973
	Onions	Sprout inhibition	+			7.5-15	30 August 1973
	Garlic	Sprout inhibition	+			7.5-15	30 August 1973
Japan	Potatoes	Sprout inhibition	+			15 max	30 August 1972
Netherlands	Asparagus*	Radurization	+			200 max	7 May 1969
	Cocoa beans*	Insect disinfestation	+		4 MeV	70 max	7 May 1969
	Strawberries*	Radurization	+		4 MeV	250 max	7 May 1969
	Mushrooms	Growth inhibition	+		4 MeV	250 max	23 October 1969
	Deep-frozen meals***	Radappertization	+			2500 min	27 November 1969
	Potatoes**	Sprout inhibition	+		4 MeV	15 max	10 May 1976
	Potatoes**	Sprout inhibition	+		4 MeV	15 max	23 March 1970
	Shrimp*	Radurization	+		4 MeV	50-100	13 November 1970
	Shrimp	Radurization	+		4 MeV	100	15 June 1976
	Onions*	Sprout inhibition	+			15 max	5 February 1971
					4 MeV	15 max	5 February 1971
	Onions	Sprout inhibition	+			5 max	9 June 1975
	Spices and condiments*	Radicidation	+		4 MeV	800-1000	13 September 1971
	Poultry, eviscerated* (in plastic bags)	Radurization	+			300 max	31 December 1971
	Chicken	Radurization	+			300 max	10 May 1976
	Fish fillets (cod or plaice)	Radurization	+			100	7 September 1976
	Fresh, tinned and liquid foodstuffs***	Radappertization	+			2500 min	8 March 1972
	Spices* ****	Radicidation	+		4 MeV	1000	4 October 1974
	Spices* ****	Radicidation	+		3 MeV	1000	26 June 1975
	Vegetable filling* ****	Radicidation	+			75	4 October 1974
	Powdered batter mix* ****	Radicidation	+			150	4 October 1974
	Endive (prepared, cut)	Radurization	+			100	14 January 1975
	Prepackaged, peeled potatoes	Radurization	+			50	12 May 1976
Philippines	Potatoes**	Sprout inhibition	+			15 max	13 September 1972

Country (Organization)	Product	Purpose of Irradiation	Type and Source of Radiation			Dose (krd)	Date of Approval
			Co-60	Cs-137	Electrons		
South Africa	Papayas					50-100	August 1978
	Onions					2-15	August 1978
	Chicken					200-700	August 1978
	Mangoes	Control of ripening	+	+		75-125	August 1978
	Potatoes	Sprout inhibition	+			12-24	19 January 1977
	Strawberries					100-300	August 1978
	Dried bananas* ****					50 max	August 1977
	Avocados* ****					10 max	August 1977
	Garlic					2-15	August 1978
Spain	Potatoes	Sprout inhibition	+			5-15	4 November 1969
	Onions	Sprout inhibition	+			8 max	1971
Thailand	Onions	Sprout inhibition	+			10 max	20 March 1973
Union of Soviet Socialist Republics	Potatoes	Sprout inhibition	+			10	14 March 1958
	Potatoes	Sprout inhibition			1 MeV	30	17 July 1973
	Grain	Insect disinfestation	+			30	1959
	Fresh fruits and vegetables*	Radurization	+			200-400	11 July 1964
	Semiprepared raw beef, pork, and rabbit products (in plastic bags)*	Radurization	+			600-800	11 July 1964
	Dried fruits	Insect disinfestation	+			100	15 February 1966
	Dry food concentrates (buckwheat, mush, gruel, rice pudding)	Insect disinfestation	+			70	6 June 1966
	Poultry, eviscerated (in plastic bags)*	Radurization	+			600	4 July 1966
	Culinary prepared meat products (fried meat, entrecote)(in plastic bags)*	Radurization	+			800	1 February 1967
	Onions*	Sprout inhibition	+			6	25 February 1967
	Onions	Sprout inhibition	+			6	17 July 1973

Country (Organization)	Product	Purpose of Irradiation	Type and Source of Radiation			Dose (krd)	Date of Approval
			Co-60	Cx-137	Electrons		
United Kingdom	Any food for consumption by patients who require a sterile diet as an essential factor in their treatment	Radappertization					1 December 1969
United States of America	Wheat and wheat flour (changed on 4 March 1966 from wheat and wheat product)	Insect disinfestation	+			20-50	21 August 1963
				+		20-50	2 October 1964
					5 MeV	20-50	26 February 1966
	White potatoes	Sprout inhibition	+			5-10	30 June 1964
				+		5-10	2 October 1964
			+	+		5-15	1 November 1965
	Chicken breast, pork link sausage, pork chops, bacon, ham, beef steaks, ground beef patties*** ++	Radappertization					
Uruguay	Potatoes	Sprout inhibition	+			8	23 June 1970
*****World Health Organization	Potatoes**	Sprout inhibition	+	+		15 max	12 April 1969
	Potatoes	Sprout inhibition	+	+	10 MeV max	3-15	7 September 1976
	Onions+	Sprout inhibition	+	+	10 MeV max	2-15	7 September 1976
	Papaya	Insect disinfestation	+	+	10 MeV max	50-100	7 September 1976
	Strawberries	Radurization	+	+	10 MeV max	100-300	7 September 1976
	Wheat and ground wheat products**	Insect disinfestation	+	+	10 MeV max	75 max	12 April 1969

Country (Organization)	Product	Purpose of Irradiation	Type and Source of Radiation			Dose (krd)	Date of Approval
			Co-60	Cs-137	Electrons		
****World Health Organization	Wheat and ground wheat products	Insect disinfestation	+	+	10 MeV max	15-100	7 September 1976
	Rice+	Insect disinfestation	+	+	10 MeV max	10-100	7 September 1976
	Chicken	Radurization, radicidation	+	+	10 MeV max	200-700	7 September 1976
	Cod and redfish+	Radurization, radicidation	+	+	10 MeV max	200-220	7 September 1976

*--experimental batches
**--temporary acceptance
***--hospital patients
****--test marketing
+--provisional
++--special exception
underlined--unlimited clearance
*****--IAEA/FAO/WHO Expert Committee for evaluation of irradiated foods has recommended acceptance of the foods listed.

APPENDIX II.

PILOT AND COMMERCIAL FOOD IRRADIATION PLANTS

Country	Equipment	Location	Purpose
United Kingdom	Co-60 source, 300 000 curies	Wantage Research Laboratory of the Atomic Energy Research Establishment	
France	Cs-137, 175 000 curies	Mobile irradiation unit "IRMA" owned by Societe Conservatom Recherches, based at the regional "Centre d'Etudes Nucleaire" (CEN) at Saclay	
Belgium	Two Co-60 irradiators	Industrial-scale pilot plant under construction in 1977 for the Institut National des Radioéléments (I.R.E.), was to be operational in late 1978	Multipurpose pilot plant
Iceland		Pilot-scale facility, joint project of the Government of Iceland, the IAEA, and the US Atomic Energy Commission	(fish, seafood)
Netherlands	Co-60	Stichting Proefbedrijf Voedelbestraling at the Institute for Atomic Sciences in Agriculture, Wageningen	Multipurpose pilot plant

Country	Equipment	Location	Purpose
Spain	Co-60, 500 000-curie capacity	Centro Nacionalde Energia Nuclear (JEN), Madrid	Industrial-scale irradiation facility
Italy	Co-60, 150 000-curie Two Co-60 units - 10 000 curie capacity	Gammatron, s.p.a., Coma	Industrial-scale multipurpose facility
	Co-60, 140 000-curie capacity	Gammarad Italia, Bologna	Industrial-scale irradiation facility
		Located in Fuccino area, construction completion slated for October 1980	Industrial vegetable irradiator
		Applied Radiation Division of the C[illegible]ssaccia Nuclear Center	Pilot-scale tests
South Africa	Three Co-60 units	Radiation Technology Facility of the National Nuclear Research Center, Pelindaba	Multipurpose pilot plant
	Co-60	Letaba Cooperative Ltd., Tzanenn	Pilot plant
Japan		Taskasaki Radiation Chemistry Research Establishment of Atomic Energy Research Institute, Tokyo	Pilot plant
		Shihoro Agricultural Cooperative Association, Hokkaido	Commercial facility

Country	Equipment	Location	Purpose
Israel	Co-60	Sor Van Ltd., near Soreq Nuclear Research Center, Yavne	Multipurpose commercial facility
	Co-60, 30 000 curies	Soreq Nuclear Research Control Center, Yavne	Pilot scale
Egypt	Gamma-Top 1 million curie capacity gamma irradiator	National Center for Radiation Research and Technology, Cairo	Multipurpose pilot facility
	1.5 MeV electron beam accelerator to be installed in 1979		
India		Pilot-scale plant constructed as part of a joint effort of the Food Corporation of India and the Department of Food, Ministry of Food and Agriculture, Government of India	
	Three Co-60 units	Bhabha Atomic Research Center, Bombay	
Thailand	Co-60 Gammabeam-650	Atomic Energy for Peace Center, Bangkok	Irradiate onions for commercial firms
Argentina	Co-60	Located at Ezeiza, Province of Buenos Aires	Semi-industrial plant

Country	Equipment	Location	Purpose
USSR	Co-60, 240 000 curies	All-Union Scientific Research Institute of the Canning and Dehydrated Vegetable Industry, Bogucharov Branch in Tula Oblast	Pilot plant
	Co-60, 357 000 curies	All-Union Scientific Research Institute of Grain and Allied Products	Pilot plant
	Electron accelerators	Institute of Nuclear Physics, Academy of Sciences, Siberian Department	Pilot plant
	Co-60 source, 60 000 curies (capacity for 150 000 curies)	Institute Depot for Fruit and Vegetable Procurement, Moscow	Production scale
East Germany	Co-60	Central Institute of Nuclear Research, Rossendorf	Multipurpose pilot plant
Czechoslovakia	Co-60	Nuclear Research Institute, Řež	Pilot plant
	Co-60	Two pilot-scale facilities, locations unknown, are under construction	
Hungary	50 000 curies	Central Food Research Institute, Budapest	Pilot plant
Bulgaria	Co-60	Constructed at the largest fruit and vegetable processing factory at Kritshim, near Plovdiv	Pilot-scale irradiation

APPENDIX III.

COUNTRIES WITH ACTIVE FOOD IRRADIATION PROGRAMS AND COMMODITIES UNDER INVESTIGATION

Country	Meats and Poultry	Fish	Fruits and Vegetables	Cereal Products	Dairy Products	Spices	Dehydrated Vegetables
Australia	X	X	X	X			
Austria			X	X			
Bangladesh		X	X	X			
Belgium	X	X	X				
Brazil			X	X			
Bulgaria	X		X	X			
Canada	X	X	X	X		X	X
Chile			X				
China (Taiwan)			X		X		
Cuba							
Czechoslovakia	X		X	X			
Denmark			X				

Country	Meats and Poultry	Fish	Fruits and Vegetables	Cereal Products	Dairy Products	Spices	Dehydrated Vegetables
East Germany			X				
Egypt	X	X	X	X			
Finland		X					
France		X	X	X			
Germany	X	X	X	X	X	X	
Ghana							
Hungary	X		X	X		X	
Iceland		X					
India	X	X	X	X			
Indonesia	X	X		X	X		
Iran	X	X	X	X			
Iraq			X				
Israel			X				X
Italy	X	X	X				
Japan	X	X	X	X			X

Country	Meats and Poultry	Fish	Fruits and Vegetables	Cereal Products	Dairy Products	Spices	Dehydrated Vegetables
Mexico	X		X	X			
Netherlands	X	X	X				
New Zealand	X	X	X	X			
Nigeria			X				
Norway		X	X			X	
Pakistan			X	X			
Philippines	X	X	X			X	
Poland	X		X			X	
Portugal	X		X				
Republic of Korea	X		X	X			
Romania	X		X				
South Africa	X		X				
Spain		X	X	X			
Sri Lanka				X			
Sweden			X				

Country	Meats and Poultry	Fish	Fruits and Vegetables	Cereal Products	Dairy Products	Spices	Dehydrated Vegetables
Switzerland	X	X	X	X	X		
Thailand		X	X				
Turkey	X		X		X	X	
USSR	X		X	X			
United Kingdom	X	X	X	X	X		
Uruguay			X				
Venezuela	X		X				
Yugoslavia						X	

GLOSSARY

Rad . . . . Quantity of ionizing radiation that results in the absorption of 0.01 joules of energy per kilogram of irradiated material.

Radappertization . . . . . Sterilization. Irradiation doses are $\geq$2.5 Mrd or $\geq$1.0 Mrd in combination with heat treatment.

Radicidation . . . . Destruction of pathogens. This term usually applies to meat, poultry, fish, and spices. Irradiation doses range from 0.075 Mrd to 1.0 Mrd.

Radurization . . . . Extension of shelf life; inhibition of sprouting or maturation; disinfestation; inhibition of mold. Irradiation doses range from 0.10 Mrd to 0.30 Mrd, with higher doses for meat. This has the broadest meaning and usage of the three irradiation process terms.

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